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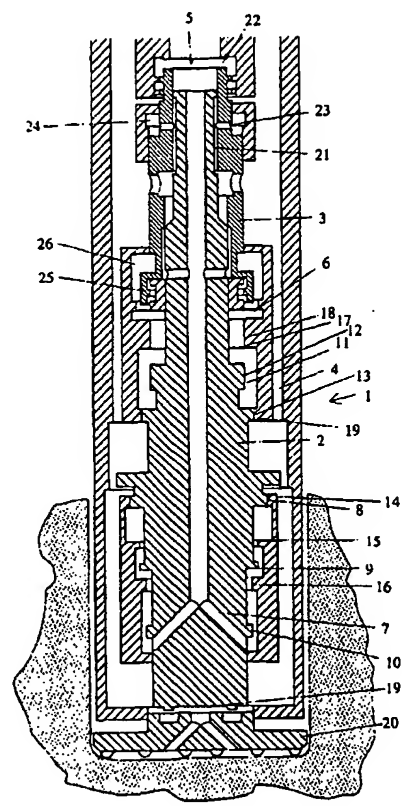
(57) Abstract

A percussive hammer for use in-the-hole hammer percussive drilling using water pressure to drive the percussion hammer, the hammer having a piston cylinder combination which provides for multiple stages where there are successive effective piston areas of diminishing size for both return and impact directions which minimises peak pressures from water hammer effects. A dual piston arrangement with hydraulically linked pistons which are both driven by successive effective piston areas of diminishing size for both return and impact directions for each piston is also disclosed.



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PERCUSSION DRILLING IMPROVEMENTS

This invention relates to percussion drilling improvements and in particular to the case where such drilling apparatus is driven by liquid at pressure.

It has previously been known to use in-the-hole reciprocating percussive motors which are driven by air pressure.

There are advantages possible by using liquid (usually water) instead of air but problems have been experienced in trials when an in-the-hole liquid driven percussive motor is used.

One of these problems to which this invention is directed relates to the problem of water hammer which is conventionally causes high pressure peaks (when the velocity of a long column of water is caused to be rapidly changed).

Such high pressure peaks can place great stress on seals and other constraining parts.

A number of differing techniques have been tried in order to adequately reduce the pressure peaks which would result if conventional equipment. was used

Previous trials have included a column of air to act as a buffer. Such an arrangement has not worked successfully when trialed over an extended period of time. Other attempts have included the use of other buffering devices but again where metal components have been used metal fatigue has caused a high and early failure rate..

The object of this invention is to provide a different arrangement from those previously used by which a reduction in the pressure peaks can be achieved..

According to this invention this can be said to reside in a percussive hammer to be used for in-the-hole hammer percussive drilling using liquid pressure to drive the percussion hammer characterised in that the hammer includes a piston member within a cylinder adapted to move through at least two stages

during its impact stroke where during one stage there is provided an effective piston area which is different from that of the effective piston area offered during the other stage, the hammer being arranged such that supply of liquid pressure during the stage with the lesser effective piston area will be connected only subsequent to the supply of liquid pressure being supplied during the stage with the larger area where the two stages are while the piston member is caused to outwardly accelerate to an impact location.

In this way, the flow rate of supply fluid required to accelerate the piston member during successive stages would be reduced if this piston started each new stage at rest. However, because the piston is increasing its speed, the smaller effective piston area will result in a more constant flow rate.

There will be achievable therefore a flow rate of the liquid overall which will be less subject to abrupt change and hence cause of any high pressure peaks.

In preference, there is also provided such an arrangement for the return stroke to be handled in the same way as the impact stroke.

In preference, the number of stages used is increased above two both for the outward stroke and the return stroke of the piston member.

In preference, the liquid used is water.

In preferable alternative, there are provided two piston members within the same cylinder arranged to act in mutually opposing directions and where one of the piston members provides a cylinder shape to interact with the other piston member as a cylinder.

In preference, where there are two piston members within the same cylinder, there is provided a chamber filled with water and within which each of the piston members defines a part of the chambers area with an effective piston area equal to that of the other piston member and where the chamber is closed to external access and is filled with water.

The result of this last arrangement is to constrain the respective motions of the two piston members to maintaining a common volume within the chamber and hence substantially hydraulically interlock the relative motion directions of the

two members to respectively reciprocate.

In preference, there is arranged to be met at the end of the return stroke of the piston member a closed chamber filled with water to act as a return stroke buffer.

For a better understanding of this invention it will now be described with reference to the preferred embodiments which shall be described with the assistance of drawings in which

FIG 1 is a schematic cross sectional view shown schematically only of a percussion hammer according to a first embodiment incorporating a valve to effect reversal of flow;

FIGS 2, 3, 4 and 5 are cross sectional views of the piston and cylinder parts of a percussive hammer according to a second embodiment but using the arrangement as schematically illustrated in FIG 1 as a six stage single piston motor;

FIG 6 is an arrangement according to a third embodiment shown schematically being a three stage dual piston percussive motor;

FIGS 7, 8 and 9 are cross sectional views of a percussive hammer being a three stage dual piston hammer according to a fourth embodiment the drawings being somewhat schematic and being shown without any valve arrangement but intended to be using a valve system as illustrated in FIG 6.

Referring to the drawings in detail there is shown in FIG 1 in a schematic arrangement, a percussive hammer 1 which includes a piston member 2 , a valve member 3 and a cylinder 4.

The piston member 2 has a central passageway 5 with outlets at 6 and 7 for supply of water at substantial pressure.

Surrounding the piston member 2 and defining with respective piston segments of the piston member 2 is the cylinder 4.

Each of the piston areas is being shown at 8, 9 and 10 at one end of the piston

member 2 and 11, 12 and 13 at the other end of the piston member 2. These are selected so that as they are each presented with water at pressure by reason of their respective coincidence with an inward extending part of the cylinder such as at 14, 15 and 16 in the one case and 17, 18 and 19 in the other, where there is thereby provided an effective piston area which as the piston member 2 is being caused to accelerate toward an outermost impact location which is to say the end at 19 will impact the simulated bit at 20 then each effective piston area which will be acted upon by fluid at pressure will be smaller.

As will be seen by the schematic drawing of FIG 1 there are therefore six different effective piston areas. The piston member 2 begins its return stroke after striking the bit (piston members 11,12 and 13 being exposed at the same time to exhaust pressure). By having effective pressure from the high pressure water supply passing through conduit 5 and through outlets 7 and by-passing piston elements 10 and 9 there is applied pressure to the largest effective piston area at 8 through cylinder 14. As the piston member 2 therefore is caused to accelerate toward its inward location, the next piston segment 9 comes into coincidence with cylinder part 15 which thereby defines a smaller effective piston area. The next piston segment 10 comes into coincidence with cylinder part 16.

The distance between the respective piston segments and their relative location for coinciding will be cylinder parts such that as a first effective and largest piston area comes out of coincidence, the next one is located so that there is effectively a seamless transfer. Therefore there can be caused minimal sudden abrupt stopping or starting of full flow of the liquid at pressure. In this way, the volume of liquid required to fill the cylinder area progressively decreases but this is offset by the increasing speed of the piston. Accordingly, the rate of change of flow through the period or stages of the full stroke of the piston is reduced substantially. At the end of the return stroke, the piston member 2 brings into coincidence channel 21 between the source of high pressure fluid at 22 and channel 23 in the valve member 3. This accordingly pressurises chamber 24 which has the result of causing the valve member 3 to move outwardly which in turn brings the part 25 of the valve 3 into a position which will cause a supply of pressure fluid to then enter the area at 26. This will cause area 26 to be high pressure instead of low pressure. Pistons 8,9 and 10 in cylinder areas 14, 15 and 16 are successively

exposed to high preassure during a forward stroke as they were during the return stroke.

At the beginning of the forward stroke, the pressure against piston 11 in cylinder 17 acts against piston 10 in cylinder 16. During the second stage of the forward stroke , piston 12 in cylinder 18 acts against piston 9 in cylinder 16. At the end of the forward stroke, piston 13 in cylinder 19 acts against piston 8 in cylinder 14.

In each case , of pairs of pistons acting against each other , the differential or effective piston area is reducing as the different stages engage.

In the embodiment shown in figure 1, pistons 11 and 12 have been made the same size and cylinders 17 and 18 become coincidental. Such an arrangement saves on overall length and can be used if the piston speed will be appropriate after reversal of direction.

Again therefore as the piston is caused to accelerate, successive effective piston areas are reduced through each of the three stages. This will ensure that a the fluid flow will be caused to be kept at a reduced pressure peak.

Upon impact there is again caused a change in position of the valve 3 relative to the cylinder and body 4 causing the return direction of fluid flow once again through 26. Space 26 is exposed to exhaust pressure while conduit 7 continues to supply high pressure fluid to pistons 8,9 and 10 and cylinders 14,15 and 16.

This description is in relation to a schematic layout where the purpose of the description is to illustrate the principle by which succeeding effective piston areas can be arranged to achieve the result required.

A more practical illustration of how this will be carried out in practice is now described without a corresponding valve system being shown for sake of simplicity in FIGS 2, 3, 4 and 5.

These four drawings show sequentially a range of positions where there can be seen their respective three stages for the outward impacting stroke and the equivalent three stages for the return stroke.

Accordingly, there is a cylinder body 27 and a piston member 28. Dumping of

water through to the bit is achieved through channels 29 from the valve exhaust and between cylinder sets The supply of water at high pressure is achieved through the central conduit 30 through the centre of the piston member 28 to pistons for the return stroke. It is supplied to pistons 39 and 41 from the valve for the forward stroke.

The water exits for the return stroke through channel 31 and on the return stroke firstly bears against cylinder segment 32 as shown in FIG 5 then as this clears the cylinder part 33, the next piston segment 34 coincides with cylinder segment 36 and finally piston segment 37 coincides with cylinder segment 38.

For the downward impacting stroke, there is firstly piston segment 39 coinciding with the cylinder segment 40 then piston segment 41 with cylinder segment 42 and finally there is coincidence of piston segment 32 with the cylinder segment 33.

Now referring to FIG 6, this shows in schematic detail only the relative locations that can be used for a dual piston system incorporating the concept of this invention.

Accordingly in this embodiment there are provided two piston members 43 and 44.

The two piston members are kept in relative association with each other by having respective parts shown at 45 in the case of the outer piston and at 50 in the case of the inner piston 43 such that there is confined in chamber area 46 a quantity of water which will not vary.

This effectively hydraulically couples the two piston members 43 and 44 together and causes them to act with a 180 degrees out of phase motion to cancel volume change between the bit and pistons. In this case then there is further provided a valve 51 the operation of which is substantially the same as the valve as described in relation to the embodiment described in FIG 1 and which has for its purpose to change the direction of flow being supplied from the high pressure source at 52 to direct this into the area 53 to effect the downward stroke of the central piston member 43 while at the same time causing the reciprocal motion of the outer piston 44.

Again the function of effective piston areas is used in successive alignments

so that as the respective piston that is in each case 43 and 44 is caused to accelerate respectively toward an outer impact location or toward a return location, the effective piston areas are chosen so that there would be a reduced volume of liquid required if the speed of the piston was kept constant but as this is accelerating, will more match the area with the speed so as to reduced substantially changes in pressure effecting water hammer effects in the pressure supply and return lines.

As will be now relatively apparent, water at pressure coming through the conduit 52 and entering through channel 54 will pass through area 55 to impinge against piston segment 56 then as the piston rises through its return stroke in succession piston segment 57 and piston segment 58 will coincide respectively with cylinder segment 59 and 60.

As the effective pressures here are essentially equal and opposite, when the pressure to return the central piston member 43 is effected, this will in turn assist in providing effective pressure to cause the outer piston 44 to proceed through its forward stroke. During the forward stroke of the central piston there will be an initial pressure on piston segments 61 followed by segments 62 and 63. In this embodiment piston segments 61 and 63 are of the same diameter.

Likewise however for the central piston there will be an initial pressure on cylinder segment 61 then in turn segment 62 and 63.

In this way the central piston 43 is a master piston and the outer piston 44 acts as a slave piston. The balanced counter oscillation means that there is no net change in the volume of water between the pistons and bit if the annular impact area of the slave piston equals the circular impact area of the master piston. The oscillating flows from supply to return through the pistons lower total flow losses.

A significant advantage of this arrangement is that because there is this hydraulic linkage between the two pistons, this enables them to move together but 180 degrees out of phase and it furthermore provides a transfer of energy so that as either piston strikes the bit, the energy of the other piston is added to the striking piston. The mass of the striking piston is effectively equal to the mass of both pistons.

This arrangement furthermore has a potentially higher operating impact frequency than the previously described single piston design. The higher frequency can be partially exchanged for a longer stroke higher piston velocity and thus a higher impact energy. The selection of the relative piston segments and the cylinder segments is also chosen to make assembly of the apparatus convenient.

For a more specific description of the dual piston three stage arrangement I now refer to FIGS 7, 8 and 9 wherein there is shown again without a valve system for the sake of simplicity and recalling that various valve systems could be used according to known technology, there is a piston 64 acting as the master or inner piston and the outer or slave piston 65 the chambers that hydraulically interlock the master piston 64 and the slave piston 65 are shown at 66A and 66B.

There is a central supply of water provided through central conduits 67 and the respective relative locations of the piston segments at 68, 69 and 70 are matched to the effective cylinder parts at 71, 72 and 73 on the inner side of the slave piston 65.

This then describes in a general sense the way in which two embodiments can be put into place and from which will be seen that significant reduction in water hammer effect can be achieved.

There are advantages in using the dual piston system in that energy is transferred to the bit at the end of the each stroke and does not have to be stored or wasted at the end of the return stroke.

The existing single piston hammer does waste some energy at the end of the return stroke. The piston is "bounced on a trapped volume of water at the end of the return strokewhen the valve closes both the supply and exhaust ports for a short time. During this period, some high pressure water is dumped to maintain flow and minimise water hammer.The energy in the dual piston hammer return stroke becomes impact energy. For a small energy loss penalty we can fill in and round off the transitional water flow trough by allowing a metered leakage flow from supply to return during the brief changes between piston sizes and impacts.

Now referring to FIG 10, this illustrates based upon calculations the improvements achieved in reduction of peak pressures.

The graph shows flow rates in litres per second and speed in meters per second on the left hand vertical axis, across the base, time in milliseconds and up the right hand vertical side distance in millimetres.

The graph shown at 74 is the flow rate in litres per second, the speed 75 is given in metres per second and finally distance travelled is given at 76

What will clearly be seen by this graphical illustration is the significant reduction in flow rate changes by reason of the change in effective piston area sizes successively through the respective stages.

Finally the parts are in preference arranged so that the piston is bounced on a trapped volume of water at the end of the return stroke.

While the description refers to a valve to effect piston reversal other techniques are known and can be used for this function. For instance it is possible to use high pressure supply water alone to reverse the piston but the stroke would then need to be bigger for the same piston size and more energy would be lost. All of the piston kinetic energy can be lost using this concept.

It will be well understood that variations can be applicable to the specific description.

Claims :

1 A percussive hammer to be used for in-the-hole hammer percussive drilling using liquid pressure to drive the percussion hammer characterised in that the hammer includes a piston member within a cylinder adapted to move through at least two stages during its impact stroke where during one stage there is provided an effective piston area which is different from that of the effective piston area offered during the other stage , arranged such that supply of liquid pressure during the stage with the lesser area will be connected only subsequent to the supply of liquid pressure being supplied during the stage with the larger area where the two stages are while the piston member is caused to outwardly accelerate to an impact location.

2 A percussive hammer as in claim 1 further characterised in that the hammer includes a piston member within a cylinder proceeding through at least two stages during a return stroke where during one stage there is provided an effective piston area which is different from that of the effective piston area offered during the other stage , arranged such that supply of liquid pressure during the stage with the lesser area will be connected only subsequent to the supply of liquid pressure being supplied during the stage with the larger area where the two stages are while the piston member is caused to accelerate inwardly to an inner most location.

3 A percussive hammer as in either one of the preceding claims further characterised in that the hammer includes a piston member within a cylinder adapted to proceed through three stages during its impact stroke where during each stage there is provided an effective piston area which is different from that of either of the other stages , arranged such that during each respective stage with a lesser area this will be connected to the supply of liquid pressure only subsequent to the supply of liquid pressure being

supplied during a stage with the larger area while the piston member is caused to accelerate outwardly to an impact location.

4 A percussive hammer as in any one of the preceding claims further characterised in that the hammer includes a piston member within a cylinder having three stages during its return stroke where during each stage there is provided an effective piston area which is different from that of either of the other stages , arranged such that during each respective stage with a lesser area this will be connected to the supply of liquid pressure only subsequent to the supply of liquid pressure being supplied during a stage with the larger area while the piston member is caused to accelerate inwardly to an inner most location.

5 A percussive hammer as in any one of the preceding claims further characterised in that there are two piston members within the cylinder, each being arranged as characterised in any one of the preceding claims.

6 A percussive hammer as in any one of the preceding claims further characterised in that there are two piston members within the cylinder, each being arranged in accord with the arrangement as in any one of the preceding claims and wherein a first of the piston members is coupled to the second of the piston members so that they will each move in an opposite direction to the direction of the other.

7 A percussive hammer as in any one of the preceding claims further characterised in that the arrangement is such as to result in reduced water hammer caused peak pressures.

8 A percussive hammer as in any one of the preceding claims where the liquid is water.

9 A drilling system including a drill stem with a percussive hammer as in any one of the preceding claims at its in-the-hole end

10 A method of drilling with a percussive hammer being used in-the-hole using liquid at pressure to drive the percussion hammer.

11 A method of drilling as in the immediately preceding claim further characterised in that there are means to keep water hammer effects small which comprise having the hammer include a piston member within a cylinder arranged as in any one of preceding claims.

12 A method of drilling substantially as described in the specification with reference to and as illustrated by the accompanying drawings.

13 A percussive hammer to be used for in-the-hole hammer reverse circulation percussive drilling using liquid pressure to drive the percussion hammer substantially as described in the specification with reference to and as illustrated by the accompanying drawings.

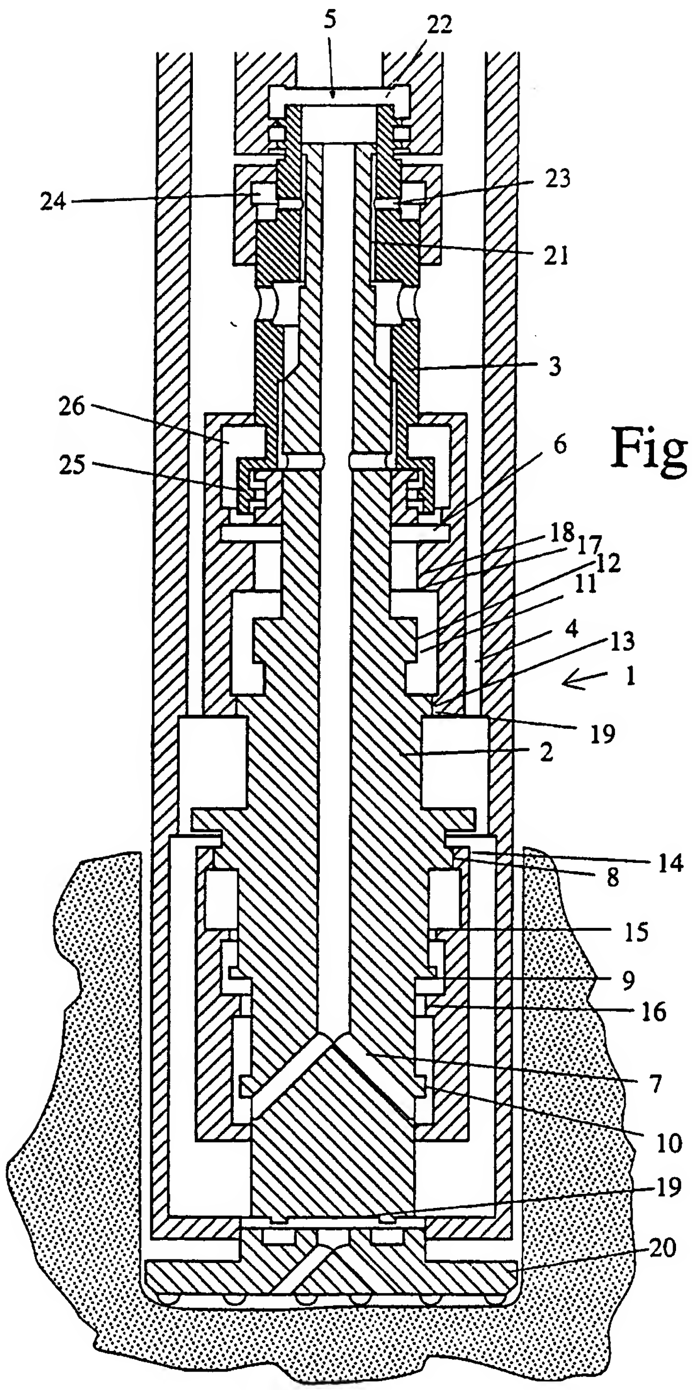

Fig 1

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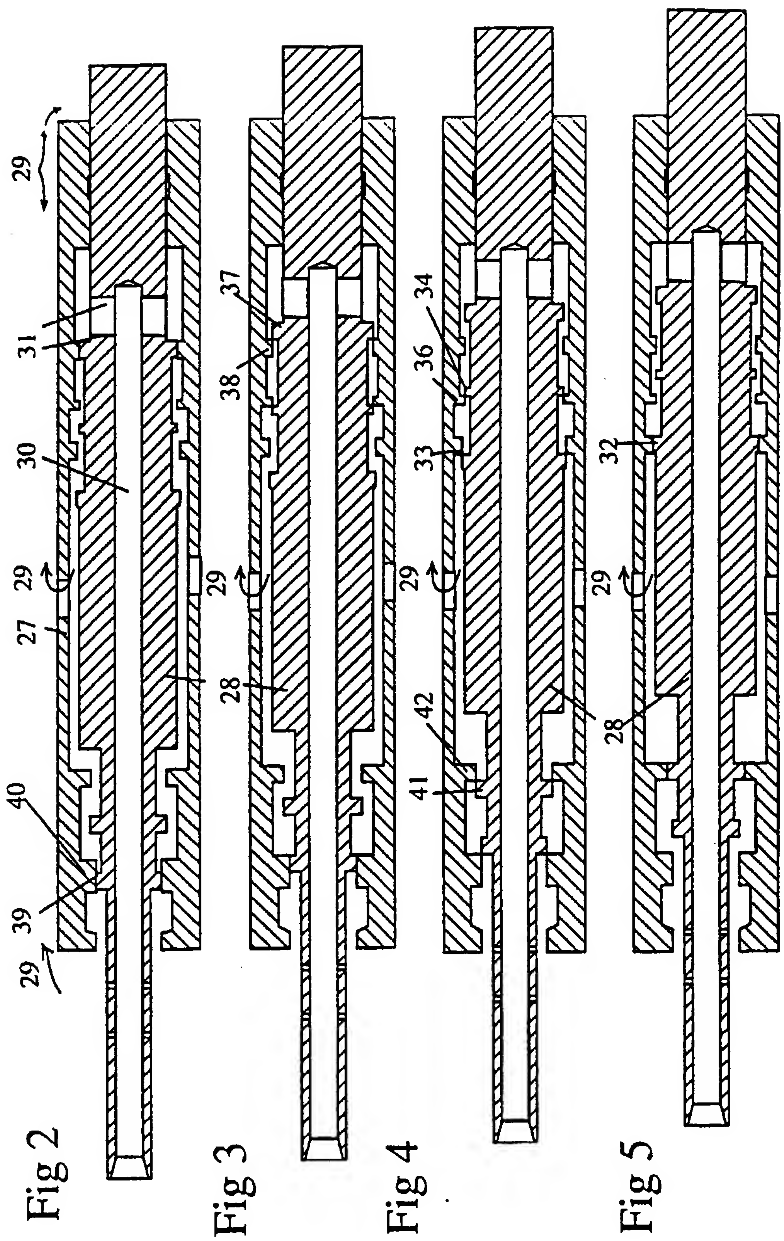

Fig 2 Fig 3 Fig 4 Fig 5

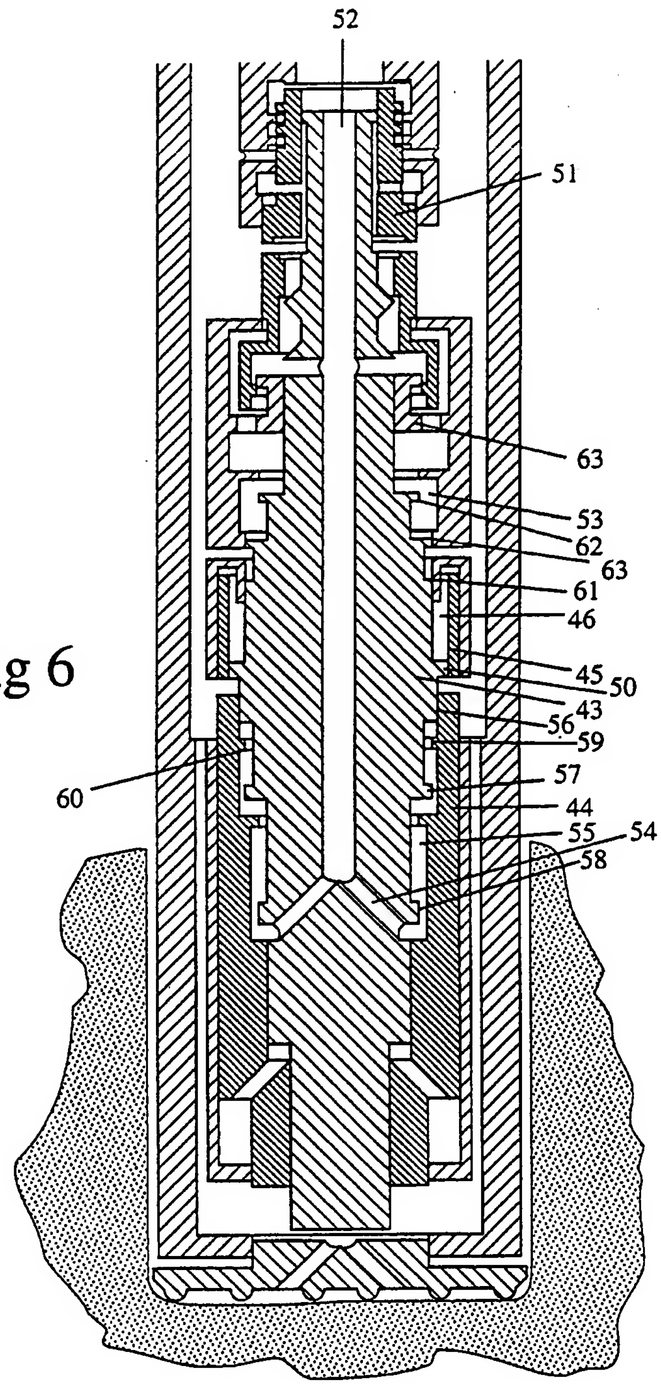

Fig 6

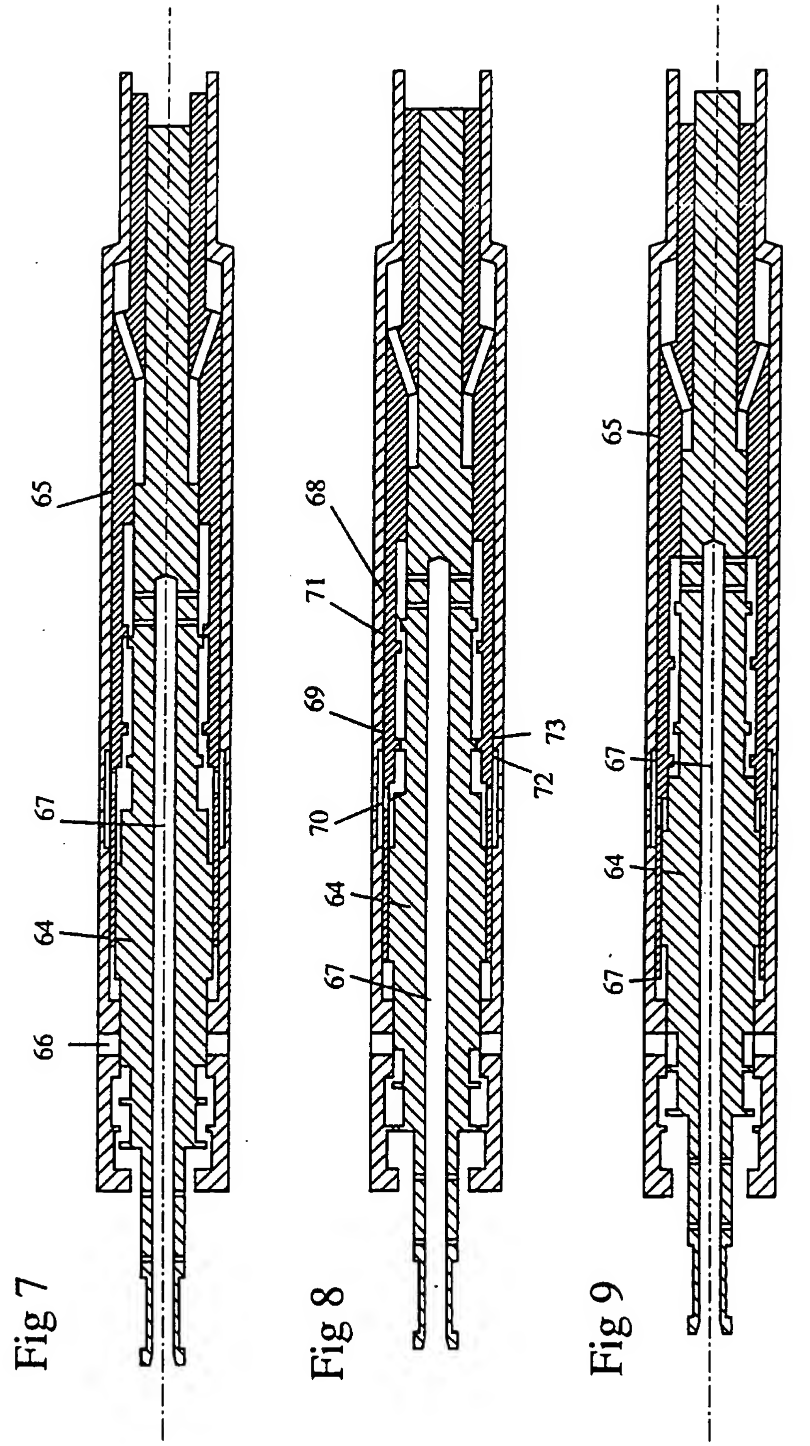

Fig 7

Fig 8

Fig 9

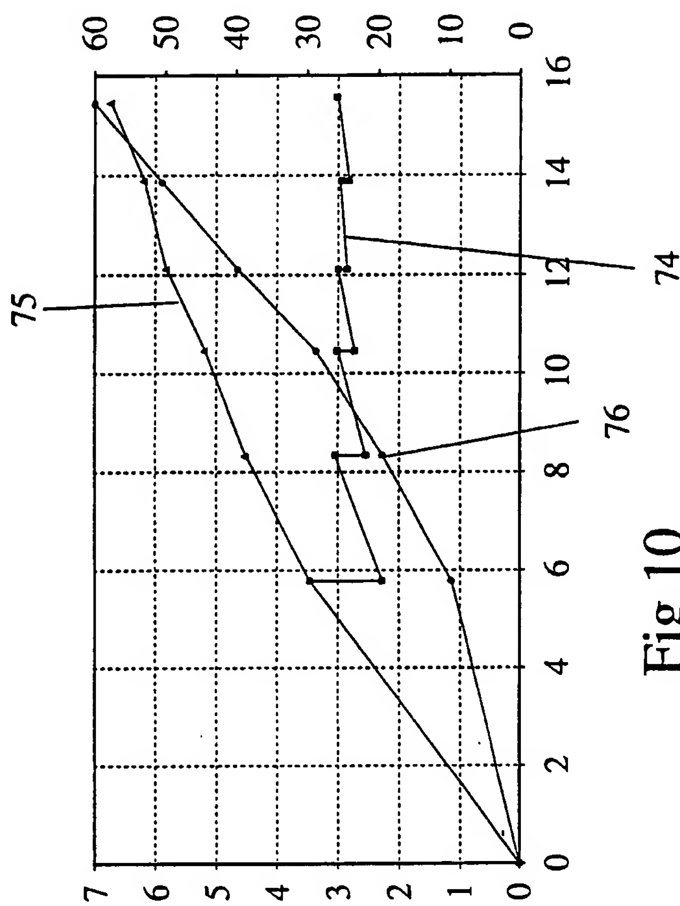

Fig 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 94/00165

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.^{5} E21B 4/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC E21B 4/14, 1/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	US, A, 4660658 (Gustafsson) 28 April 1987 (28.04.87)	
A	WO, A, 93/20322 (SDS PTY. LTD.) 14 October 1993 (14.10.93)	
A	WO, A, 92/12323 (SANDVIK AB) 23 July 1992 (23.07.92)	
A	WO, A, 92/01138 (GUSTAFSSON) 23 January 1992 (23.01.92)	
A	WO, A, 89/00638 (ATLAS COPCO AB) 26 January 1989 (26.01.89)	

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
22 June 1994 (22.06.94)	29 June 1994 (29.06.94).

Name and mailing address of the ISA/AU	Authorized officer
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Patent Document Cited in Search Report		Patent Family Member					
US	4660658	EP SE	171374 8403370	JP	61014392	NO	852510
WO	9320322	AU	38178/93				
WO	9212323	AU	11735/92	SE	9100092		
WO	9201138	AU	61442/90	EP	543806		
WO	8900638	AU NO US	20790/88 900176 5107944	EP SE	394255 8702860	FI US	900176 5014796

END OF ANNEX